Sputter-Deposition of Copper Nanoparticles onto Granular Polymeric Spacers for Enhancing Cell Wall Structure of Sintered Highly Porous Aluminum Materials

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Powder metallurgy processing has become more important in recent years, because not only higher performance in quality, reliability or durability, of metallic materials but also smaller amount of resource and energy necessary for fabricating the materials have been more earnestly demanded from the standpoint of environmental protection. In the conventional powder metallurgy processing, however, some inhomogeneous distribution of additive metallic elements over the alloy matrix is inevitable, because its approach is based on mixing additive metal powder with basic metal one. Hence it can be noted that the coated powder approach significantly decreases the inhomogeneous distribution of additive metallic elements over the alloy matrix [1], where the basic metal powder is coated with the additive metal film instead of mixing the additive metal powder with the basic metal one. Moreover, making use of this coated powder approach, it is also expected that the powder coated with the additive metal film can be sintered at lower temperature than the powder non-coated with the metal film, in case that the melting point of the film metal is lower than that of the powder metal.

On the other hand, cellular metallic materials can be also fabricated in the powder metallurgy processing by combining with a space-holder method. And it is noted that the mechanical properties or the compressive properties in particular of the cellular metallic materials are influenced by their cell wall structures. Hence it is expected that the compressive properties of cellular metallic materials fabricated in the powder metallurgy processing could be improved by enhancing the cell wall structures of the sintered porous compacts. In the present work, therefore, the deposition of copper onto acrylic resin powder in its self-convective motion [2-7] by magnetron DC sputtering was examined in order to prepare granular polymeric spacers coated with the metal, aiming at enhancing the cell wall structure of sintered highly porous aluminum materials. Furthermore the effects of the sputter-deposition of copper onto the spherical polymeric spacers on cell wall structures of the sintered porous compacts were investigated. The schematics for the enhancement of the cell wall structures in sintered porous compacts are shown in Fig.1, compared with an ordinary non-enhanced cell wall structure.

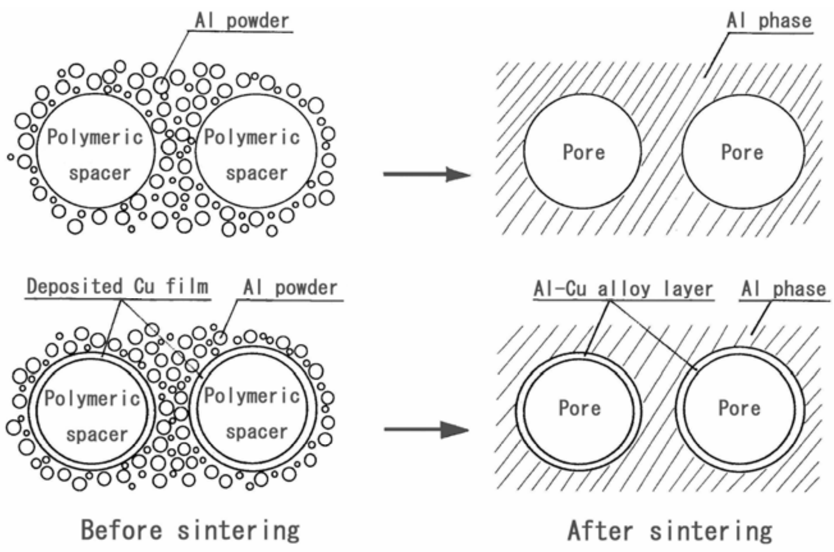


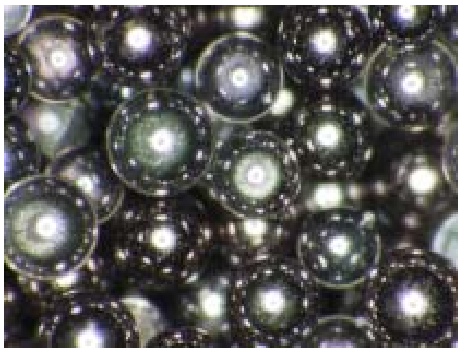
Figure 1. Schematics for the enhancement of the cell wall structures in sintered porous compacts shown in the downside, compared with that for an ordinary non-enhanced cell wall structure shown in the upside.

A vibrating-source for applying perpendicular vibration to the acrylic resin powder developed in order to perform so-called "powder-coating" in this study. A planar magnetron DC sputtering system (ANELVA Corp. type SPF210H) with a 200-mm diameter and 130-mm height stainless steel chamber was used.

The vibrating-source was installed onto a substrate holder of the sputtering system. A planar magnetron sputtering system (ANELVA Corp. type SPF210H) with a 200-mm diameter and 130-mm height stainless steel chamber was used. A planar target used for this study was a 100-mm diameter pure copper (Cu) disk. Acrylic granules (particle size: around 300μm in diameter, 3.03 g) was put onto the stainless petri-dish, which is mounted on the substrate holder and can be vibrated with the amplitude of 1mm at the frequency of 10Hz in the vacuum chamber. The self-convection phenomenon of the titanium powder occurred in the vacuum chamber evacuated to 5×10 Pa when a perpendicular vibration was applied to the powder. Argon gas was introduced at a desired flow rate into the vacuum chamber evacuated to 1×10^{-2} Pa or less.
The sputter-deposition of the copper film onto the titanium particles was carried out during the self-convection of the acrylic powder. The sputtering conditions examined in this study were as follows. Discharge voltage and current were fixed at 420V and at 0.1A, respectively. The argon flow rate was fixed at 15.0 ml/min, where the gas pressure in the camber was regulated at 22 Pa by adjusting the exhaust through the main gas valve. The deposition time for sputtering was fixed for 30 min.
Then the fabrication of porous aluminum materials was carried out in an ordinary powder metallurgy processing combined with a space-holder method using the prepared Cu coated acrylic powder in ordinary powder metallurgy processing. The tablets with 20mm in diameter were made of the pure aluminum powder mixed with a desired amount of the Cu coated acrylic powder as a space-holder, by being pressed in a cylinder with a piston. Both tablets consisting of the coated acrylic powder were pre-sintered at 400 degree centigrate for 2 hours in an argon atmosphere for the sublimation of the resinous spacer material and then sintered at 650 degree centigrate for 2 hours in a vacuum.
The effects of the sputter-deposition of copper onto the granular polymeric spacers on cell wall structure of the sintered porous aluminum materials were investigated. The porous structure of the obtained sintered compacts was observed by SEM. On the other hand, the distribution of copper atoms in the cellular aluminum materials was measured by qualitative analysis using an EPMA.

Under visual observation, the color tone of the acrylic powder obtained after the sputter-deposition looked red brown or coppery, i.e., the color tone of sputtered pure copper deposits, while that before the sputter-deposition had looked white or semi-transparent, i.e., the color tone of the acrylic powder. Thus it was assumed that the acrylic powder was coated with the copper deposits. Figure 2 shows typical optical micrographs of the acrylic resin granules before the sputter-deposition and those obtained after the sputter-deposition. The surface of the obtained granules appeared to be covered with deposited copper thin film without any peelings. Thus it was confirmed that the sputtered copper could be adherently deposited onto the surface of the acrylic resin granules.

(a) Before sputter-deposition



(b) After sputter-deposition

Figure 2. Optical micro-graphs of the acrylic resin granules before the sputter-deposition (a) and those obtained after the sputter-deposition (b).

The sintered compact obtained from the aluminum powder mixed with the copper sputter-deposited acrylic resin powder was solid and uniform, and its porosity was around 70%. Under the SEM image, it was found that the porous structure of the sintered aluminum compacts consisted of a cell structure with spherical pores of several hundred micro-meters in diameter. According to EPMA analysis, Kα X-ray peaks for Cu atoms as well as those for Al atoms were definitely detected on at the vicinity of the cell walls, while those only for Al atoms was detected on the matrix area. Thus it was found that Cu atoms were distributed at the vicinity of its cell walls, concluding that cell wall structures could be enhanced by this processing.